Mathematical Forum
Vol.28(2), 2020
ISSN: 0972-9852

Implementation of Fuzzy Logic Mamdani Model to Predict Celiac Disease in PyCharm

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Received on: 08/06/2020

Accepted on: 25/12/2020

ABSTRACT

Fuzzy logic is consistently used in the discipline of medicine for the last few decades. It is reasonable to develop fuzzy systems to predict diseases with equivocal symptoms through a fuzzy database encompassing if-then rules. But, still, celiac disease has not been prophesied with fuzzy logic technique. In this proposed fuzzy system, celiac disease prediction is attainable through symptoms by using six input parameters with one output parameter to determine the probability of disease. The system also recommends the type of clinical tests if the probable value surpasses its base limit. The study comprised of 700 individuals among them 134 celiac patients were found and analogous inputs fed into the fuzzy system which attains 98.8% accuracy, 98.5% sensitivity, 98.93% specificity with a minimal error rate of 1.14%. The proposed system was implemented using the Mamdani Model which renders excellent results in the classification of diseases. PyCharm tool was used for the evaluation of the fuzzy system to settle validation aspects along with the SPPS tool for data reduction. Furthermore, additional fuzzy libraries like skfuzzy, scipy, and matplotlib were required for model evaluation with graphical layouts. Fuzzy clustering has also been implemented to get the disease prediction value for quicker responses in the stipulated time. This proposed system will be beneficial for physicians and domain experts to predict celiac disease at an earliest without clinical testing.

***Keywords*- Celiac Disease, Crisp Inputs, Fuzzy Logic, Mamdani Model, Genetic Testing**

1. Introduction

Celiac disease is a sort of disorder which appears as a toxic agent after ingestion of wheat in the diet. Celiac disease can affect at any age without any gender distinction. It is rigid to diagnose celiac disease because ordinarily, all the symptoms that appear in the body coincide with other chronic diseases. The surgeons predict a type of gastro disorder at an early stage without any clinical testing approach, but confirmed with tTG, biopsy, EMA, Genetic testing etc. Still, it is challenging to diagnose celiac disease with few tests, but tTG is a suitable marker among them.

The term fuzzy logic refers to multi-value logic with finite boundaries range 0 to1. The methodology used in fuzzy logic is basically to tackle uncertainty and ambiguity in the data. Fuzzy logic is continuously used in the field of medicine. The conception of fuzzy logic was presented by Zadeh (1965) to tackle the problem of vagueness, imprecision, or uncertainty. With the help of a fuzzy inference system, any crisp input fed into the system, and de-fuzzification provides an output according to the data. The development of the rule-based database is feasible with if-then rules using separate operators. There are two types of models through which the fuzzy system is to be developed. i.e. Mamdani or Sugeno Model. Mamdani model is the best fit for linear complexities while the Sugeno model accommodates completeness in non-linear problems. The method of de-fuzzification is to be concocted with the center of gravity, area of maximum or other evaluation procedures. Furthermore, fuzzy clustering is to be done for the classification of disease diagnosis.

The objective of the study is to identify celiac disease based on suspected individual symptoms with crisp inputs using fuzzy logic embracing fuzzy if-then rules. Multiple scientific libraries were imported for fuzzy evaluation of rules to get a single probabilistic outcome act as celiac disease prediction with suitable recommendations.

Section II of the paper describes a literature review on fuzzy logic with several diseases and case studies on celiac disease using the clinical methodology. Section III defined the design of the fuzzy system with input-output parameters and implemented in PyCharm with Python. Section IV describes results and useful discussion on the proposed method. Furthermore, Section V describes the conclusion with future aspects of fuzzy logic with celiac disease.

2. Literature Review on Fuzzy Logic and Celiac Disease

A lot of research has previously done on celiac disease using the clinical testing technique. Recently, Falodia et al. (2019), describes case-study on 80 individuals to fix celiac disease in the north-west part of India. Enamel technique and RAS approach were used to detect celiac disease and found 33 celiac patients. In the previous year, Gulsern et al. (2019), studied on 39 individuals to diagnose celiac disease with tTG and EMA clinical testing approach. Ten celiac patients identified among them in this study. Another useful participation was given by Senapati et al. (2016) in which more than 1400 individual's diagnosed adopting latest android technology. 35 celiac patients were found in this case study and described wheat as a toxic agent.

Table 1: Study on Various diseases

Disease	Author	Methodology	Outcome
Celiac Disease	Falodia et al. [12]	RAS and Enamel approach	Participated 80 individuals with the outcome of 33 patients
Celiac Disease	Gulsern et al. [13]	EMA and tTG clinical testing	Participated 39 individuals with the outcome of 10 patients
Celiac Disease	Senapati et al. [14]	Genetic testing	Participated 1402 individuals with the

			outcome of 35 patients
Celiac Disease	Koh et al. [15]	Image Processing	System development with an accuracy of 86.47%
Chest Disease	Kayali [16]	Back-Propagation	System development with optimum sensitivity
Alzheimer Disease	Jesus et al. [17]	Mamdani Fuzzy logic approach	System development based on symptoms
Liver Disease	Satarkar [18]	Mamdani Fuzzy logic approach	Minimum rules to develop a fuzzy system with accuracy
Lung Diseases	Manikandan et al. [19]	Mamdani Fuzzy logic approach and SPSS	Participated 271 individuals with the outcome of 95% accuracy

In the perspective of fuzzy logic, Koh et al. (2019), the image processing technique was applied to diagnose celiac disease with the outcome of 86.47% accuracy confirmed via endoscopy. Kayali (2018), worked on chest disease using a similar approach for disease detection, which was profitable for doctors to diagnose chest infection. In the same year, Jesus et al. (2018), Alzheimer disease was defined with the fuzzy logic system based on symptoms with optimum accuracy. Satarkar (2017) accomplished on liver disease using fuzzy logic to develop a probabilistic method. Mamdani model was practiced to evaluate the results using the de-fuzzification technique. Manikandan et al. (2017) worked on lung diseases in MATLAB by applying fuzzy logic toolbox with SPSS software to develop a fuzzy inference system. The study was conducted in Chennai, with a questionnaire approach, participated by 271 individuals. The accuracy was recorded as 95% while diagnosing lung disease. So, these are the valuable contributions that various authors proclaimed in the last few years in the domain of medical diagnosis.

3. Design& Implementation of Fuzzy System using Mamdani Model

To design a fuzzy system to diagnose celiac disease with input symptoms, there is a provision to know the fuzzy parameters that act as crisp inputs for the proposed system. For the development, Mamdani model was used to accomplish the task for the classification of celiac disease. So, every parameter was proposed with specific fuzzy range as crisp inputs and output parameter as crisp output. The common symptoms that exist in almost all celiac patients belonged to fuzzy inputs. This proposed system incorporates six input parameters with values in particularized range as weight loss critical component, diarrhea and vomiting as usual components, abdominal pain and anemia as essential components with varied BMI. All these components need to input numerical values in the sort of crisp inputs that the proposed system should transform into fuzzy information. The evaluation process depends upon fuzzy rules stored in the fuzzy database in the arrangement of antecedent and consequent. The proposed parametric structure is illustrated in the figure1.

 ISSN: 0972-9852

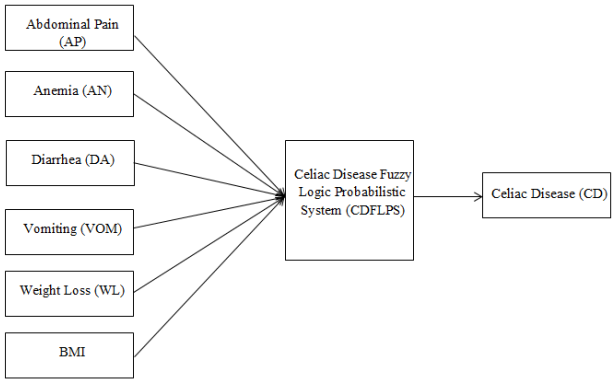

Fig. 1: Parametric Structure of Fuzzy System

To diagnose celiac disease, every input that is given to the system must resemble every single fuzzy rule of the entire database. The system exhibits unique probable value, i.e. celiac disease probability value in terms of percentage with recommendations regarding clinical testing. The working of the proposed method is depicted in figure 2. According to the Marsh classification (1992), as the weight was given to symptoms, BMI etc. to detect celiac disease, this proposed system outcomes in a similar custom to assign a percentage to every sign for celiac disease diagnosis process.

 ISSN: 0972-9852

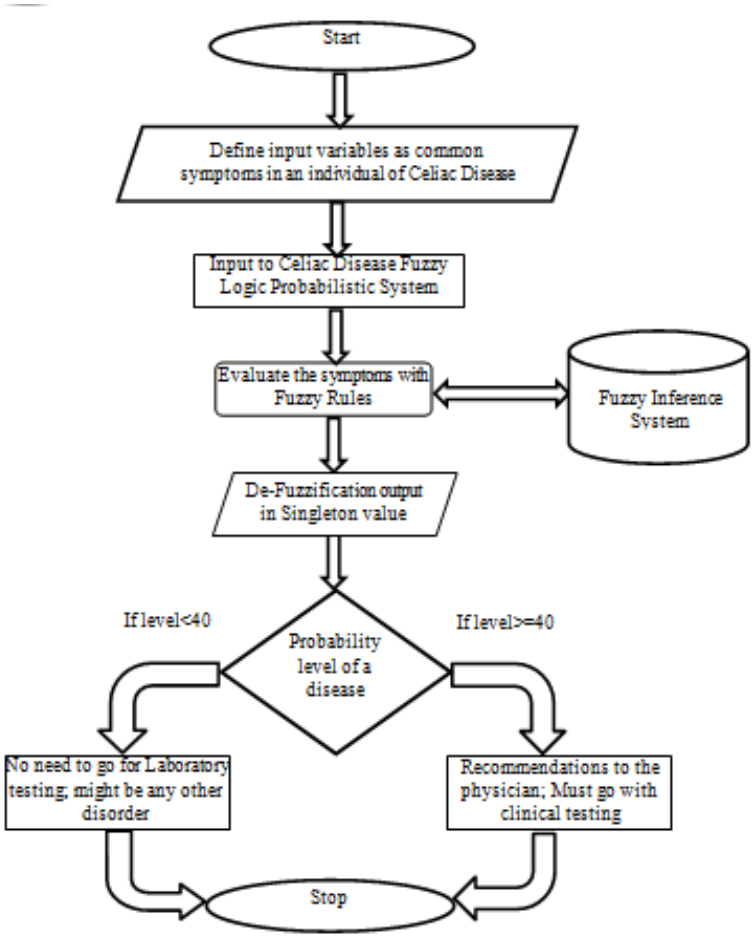

Fig. 2: Working of Proposed System

The fuzzy system was designed using the Mamdani model to predict celiac disease implemented in python using PyCharm Software. Numerous studies reveal that for predictive analysis Mamdani model is exceptionally fit in comparison with Sugeno model that often deals with nonlinear problems. To implement a fuzzy system, it needs numpy, scipy tool kit for the evaluation process to de-fuzzify the value. The input range values of various parameters related to design the proposed fuzzy system are illustrated in figure 3. First three parameters with mild, moderate and severe values in crisp format whereas vomiting with three distinct values every week. Weight loss is considered a critical parameter with two varied approaches in the form of static and losing. BMI is applied as similar to the real-time application procedure.

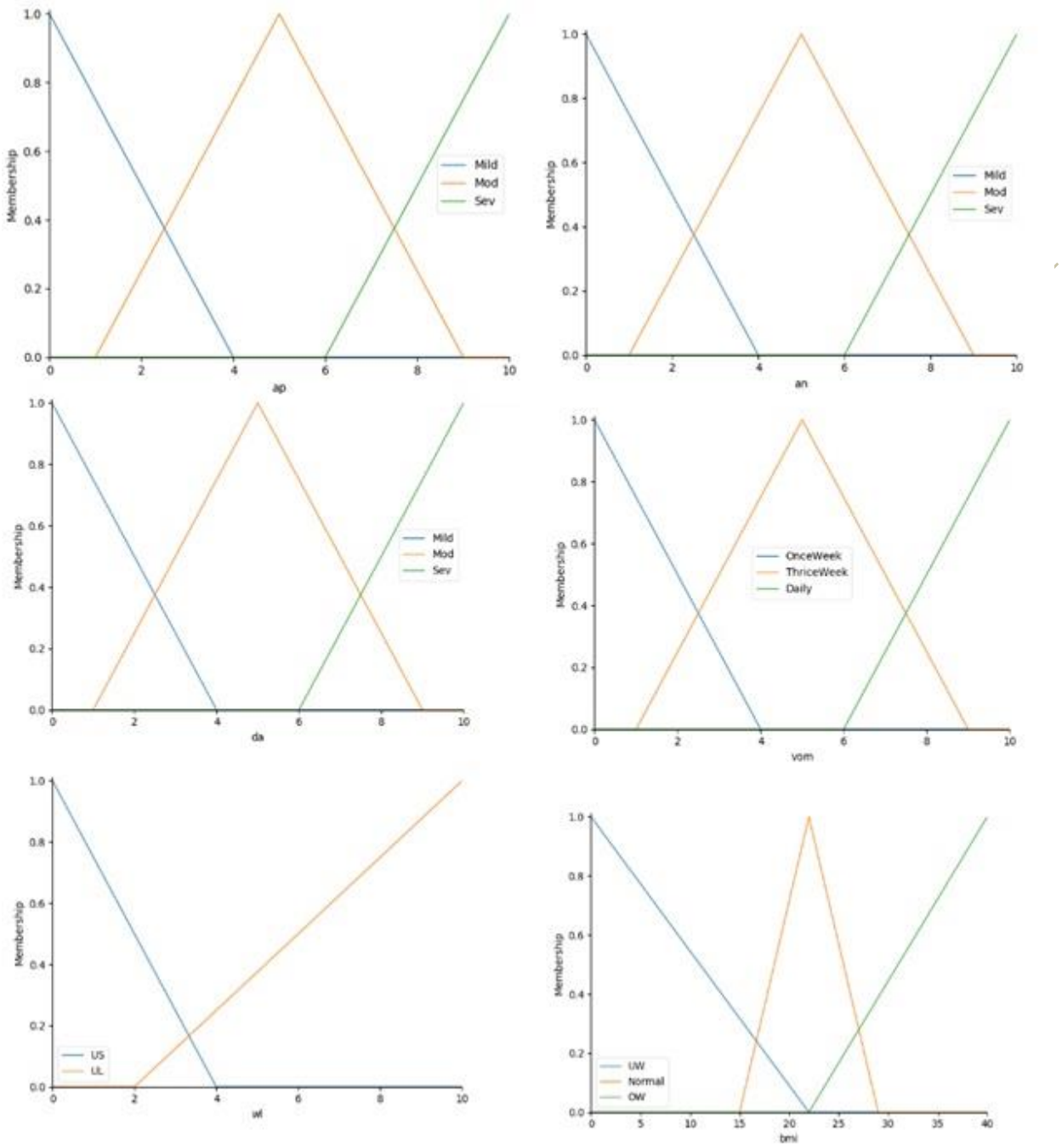

Fig. 3: Parameters with Crisp Inputs

Triangular membership function was applied for the evaluation of multiple values in the dataset with the Mamdani model. The input parameters confirm the inputs in the form of fuzzy using matplotlib function in PyCharm. The output parameter has 11 distinct crisp values to compose a consequence in terms of probability of celiac disease.

4. Results and Discussions

The implementation was done in PyCharm tool with fuzzy database where rules were stored for evaluation. The rules constituted with input parameters with a single probable parameter in terms of celiac disease using if-then combination. Suppose the input is given to the fuzzy system with values as ap = 9, an = 9.5, da = 10, vom = 9, wl = 9, and BMI = 22.143. The system delivers an output of celiac disease probability as 96.5%, as shown in figure 4. The evaluation process of the fuzzy system rivals all the given inputs with an entire fuzzy database which decompose the value using the de-fuzzification methodology. The system also offers recommendation "Strong Chance of Celiac Disease" based on the given inputs by the user.

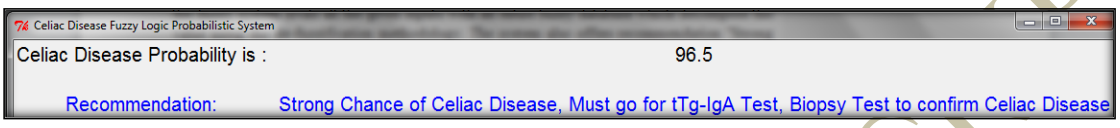

Fig. 4: Fuzzy Probable Output

The rule viewer gives an exact view of the combination of rules that equaled with the given input. The output parameter 'cd' shows a crystal picture with a fuzzy database with a matched combination. The fuzzy graph, as depicted in figure 5, represents matched rules with the given output, lies in the probability of more than 90%.

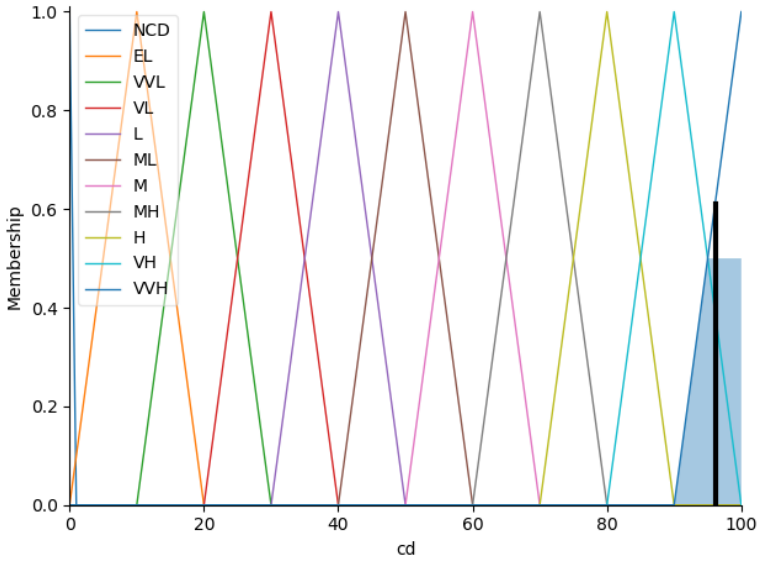

Fig. 5: Fuzzy Graph for Probable Output

The data was collected from Punjab, comprised of 700 individuals with 393 males and 307 females.Out of 700 individuals, 134 celiac patients identified and given the values of all the parameters that are as similar for the proposed fuzzy system. The same input is given to the celiac system to check its performance of the fuzzy system. 132 correct instances were found by the proposed method with 2 false-negative value as defined in table 2.

Table 2: Confusion Matrix for Celiac Fuzzy System

	Celiac Disease (+)	**Celiac Disease (-)**

Probable Celiac Disease (+)	132 (True-Positive)	6 (False-Positive)
Probable Celiac Disease (-)	2 (False-Negative)	560 (True-Negative)

Accuracy = 692/700 => 98.8%

Error Rate = 8/700 => 1.14%

Sensitivity = 132/134 => 98.5%

Specificity =560/566 => 98.93%

So, the accuracy of the system is defined as all correct submission concerning all given inputs which comes to be 98.8%. The error rate of the system is 1.14% due to asymptomatic approach. The sensitivity of the system is formed of true-positive and false-negative values as an outcome of 98.5%. The specificity of the system depends on false-positive, and true-negative scenarios come out to be 98.93%. The above-proposed system when compared with existing fuzzy logic methodologies with other chronic diseases in recent years proved its accuracy and sensitivity. The novel research on the celiac disease with fuzzy logic gives efficient results which will be propitious for experts in the medical domain and act as a benchmark for disease prediction.

Benchmark Study: The study on celiac disease detection using fuzzy logic proved to be a benchmark study in comparison with existing disease detection approaches represented in Table 3. Koh (2019) and his team members worked on celiac disease using image processing with the aid of endoscopy images to detect celiac disease. The system accomplished 86.47% accuracy via gut damage visualization. Nilashi (2018) worked on hepatitis disease using fuzzy logic approach having 93.06% accuracy of the detection system with the center of gravity evaluation.

Table 3: Benchmark Study with existing fuzzy systems

Disease Prediction	**System Outcome**
Celiac Disease using Image Processing by Koh et al. (2019) [25]	System achieved 86.47% accuracy of disease detection based on gut damage using endoscopy images
Hepatitis disease using Fuzzy Logic by Nilashi M et al. (2018) [26]	93.06% accuracy achieved by the fuzzy logic system
Lung Diseases using Fuzzy Logic by Manikandan et al. (2017) [27]	95% accuracy of the system providing 271 lung disease patients
Breast Cancer with ANFIS approach by Sagir (2017) [28]	84% accuracy using 961 mammographic images from UCI repository
Heart Disease with Neural Network by Olaniyi et al. (2016) [29]	85% accuracy using 270 samples collected from UCI repository
Dental Disease with Fuzzy Logic by Parwe (2016) [30]	Achieved 82% accuracy on 100 patients with symptoms
Diabetes Disease with ANFIS approach	85% Sensitivity, 92 % Specificity, 0.262 Mean Error

by Polat (2007) [31]	
Celiac Disease with Fuzzy Logic (The Proposed system by Thukral S and Kaur H)	98.8% accuracy, 98.5% Sensitivity and 98.39% Specificity, 134 Celiac Patients were found with 1:5 Celiac Disease prevalence ratio

Manikandan et al. (2017) developed a lung disease system in 2017, using fuzzy logic which gives 95% accuracy of the system by generating 271 suspected patients. In the same year, Sagir (2017) concocted Breast Cancer detection with the neuro-fuzzy approach using mammographic images for disease detection. Olaniyi et al. in 2016, worked on Heart disease detection using a neural network approach having 85% accuracy on 270 samples. A similar perspective was done by Parwe (2016) for dental problems which obtained 82% accuracy using the symptomatic approach. Polat (2007) revealed a diabetes disease detection system using the neuro-fuzzy technique with 92% specificity and 85% sensitivity. So, the proposed system accomplished benchmark study in the medical domain by rendering 98.8% accuracy, 98.5% sensitivity getting 134 celiac patients having a 1:5 Celiac Disease prevalence ratio.

5. Concluding Remarks and Future Outline

This proposed fuzzy system foretells celiac disease depends on the input symptoms in the precise range. The system provides accurate results with appropriate recommendations based on inputs fed into the system by the assigned individual. Through the Fuzzy Mamdani model, the system prediction is optimum for rendering the probabilistic value of disease. Through the PyCharm tool, multiple scientific libraries like scipy, matplotlib, Tkinter, skfuzzy proffer the best evaluation results with minimal time. So, the proposed system will be adequate for the doctors and domain experts to diagnose the celiac disease at the earliest. It also depreciates the time taken to detect celiac disease without any clinical testing approach. Related types of systems can be prepared in the future with optimum accuracy for detecting chronic diseases.

Conflicts of Interest

No conflict of interest was reported by the authors

Acknowledgements

Author S. Thukral is grateful to Principal, DAV College, Amritsar for his kind support and for providing necessary facilities to carry out this work.

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